Storm runoff in fresh produce farm landscapes: *Salmonella* and *E. coli* in farm irrigation ponds

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Why study *Salmonella* and *E. coli* in storm runoff?

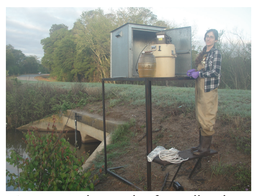
Storm runoff can transport *Salmonella, E. coli,* and other microbes into waterbodies during rainstorms, including into ponds used to store water for irrigation. In a few cases, outbreaks of *Salmonella* from fresh produce have been linked to contaminated irrigation water. *Salmonella* is the most common cause of bacterial foodborne illness in the U.S., and it is spread through feces from infected humans, livestock, wildlife, or pets. *E. coli* is found in feces even from healthy mammals, and it is considered a general indicator of fecal contamination in water.

Study design

We measured *Salmonella* and *E. coli* in pond water, stream water, and storm runoff during rainstorms at two commercial farms in south Georgia's Little watershed in 2013. Pond water samples were collected from ponds at each farm before and after storms. Stream water samples and storm runoff samples from crop fields and forested areas were collected during storm flow using automated samplers and bags placed around the ponds.

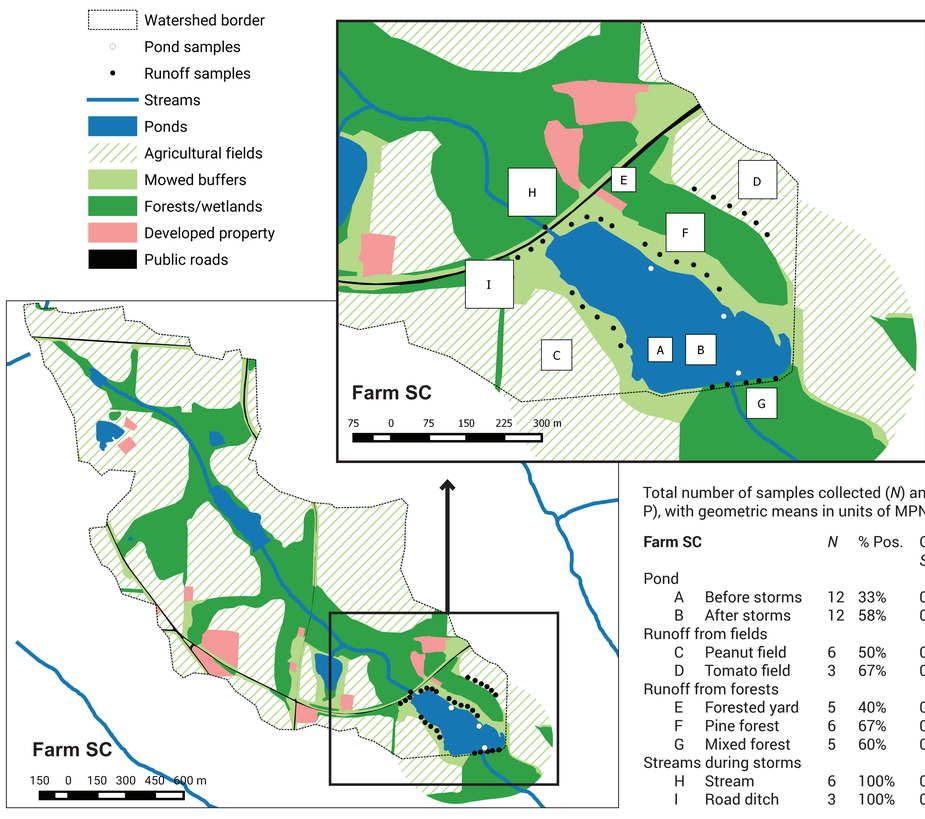
One of the two ponds

Sampling bag for collecting storm runoff at the edge of a forest



Automated sampler for collecting stream water during storm flow

Maps of sampling locations



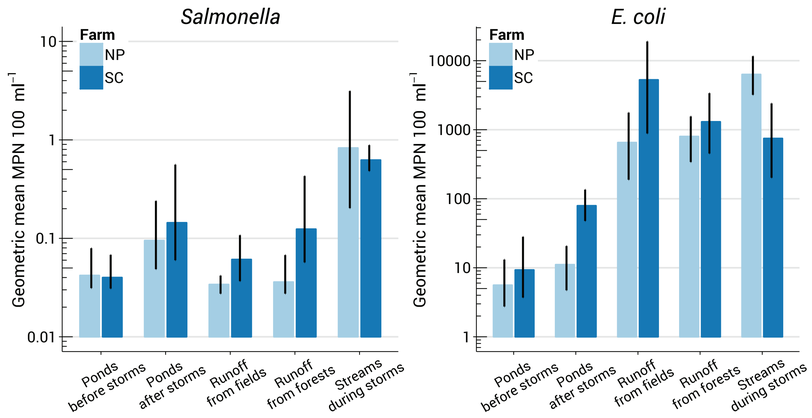
Total number of samples collected (*N*) and percent positive for *Salmonella* (% Pos.) per sampling location (A through P), with geometric means in units of MPN 100 ml^{-1} for *Salmonella* and *E. coli*.

Farm SC		*N*	% Pos.	Geom. means *Salm.*	Geom. means *E. coli*
Pond					
A	Before storms	12	33%	0.040	9
B	After storms	12	58%	0.144	79
Runoff from fields					
C	Peanut field	6	50%	0.070	5400
D	Tomato field	3	67%	0.046	5000
Runoff from forests					
E	Forested yard	5	40%	0.056	710
F	Pine forest	6	67%	0.088	2700
G	Mixed forest	5	60%	0.413	920
Streams during storms					
H	Stream	6	100%	0.767	280
I	Road ditch	3	100%	0.413	5500

Farm NP		*N*	% Pos.	Geom. means *Salm.*	Geom. means *E. coli*
Pond					
J	Before storms	12	33%	0.042	6
K	After storms	12	58%	0.095	11
Runoff from fields					
L	Biofuel field	6	33%	0.036	900
M	Peanuts/cotton	4	25%	0.030	400
Runoff from forests					
N	Shrubland	6	17%	0.031	1000
O	Mixed forest	6	17%	0.042	610
Streams during storms					
P	Stream	3	100%	0.828	6300

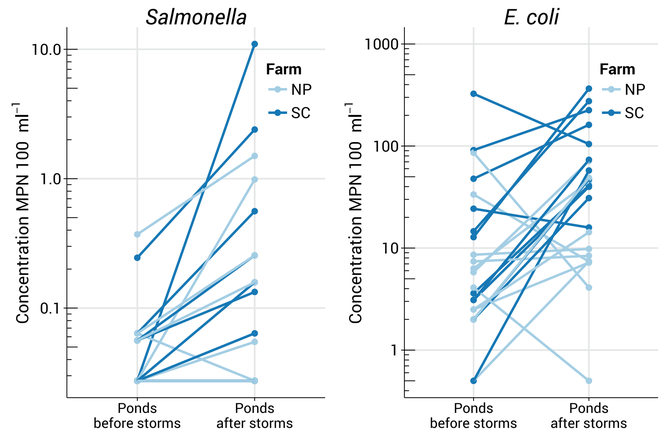
Results

- *Salmonella* and *E. coli* levels in pond water, stream water, and storm runoff (shown with 95% bootstrapped confidence intervals):



Little or no differences were seen between *Salmonella* levels in pond water and storm runoff. However, *E. coli* levels were consistently lower in pond water than in storm runoff. The highest levels of *Salmonella* overall were found in stream water.

- *Salmonella* and *E. coli* levels in pond water before and after rainstorms (each line connects samples collected before and after a given storm):



Based on linear mixed-effects models, *Salmonella* levels were higher after storms (p = 0.008) by an average of 1.05 ± 0.38 log. *E. coli* levels were higher after storms (p = 0.002) by an average of 0.62 ± 0.18 log.

Comparison with human infections

- 217 confirmed *Salmonella* infections occurred in Little watershed in 2013, and approximately 40% of those infections were linked to serotypes that appeared in our samples.
- Half (53 of 107) of all samples in our study were positive for *Salmonella*, and 72% of those positive samples were linked to serotypes implicated in human infections in Little watershed in 2013.

- *Salmonella* serotypes found in this study and in human infections (values shown are the number of samples yielding each serotype):

	Farm NP						Farm SC						
Serotype	Ponds before	Ponds after	Field runoff	Forest runoff	Streams	All	Ponds before	Ponds after	Field runoff	Forest runoff	Streams	All	Human cases in Little watershed in 2013
Anatum											1	1	1
Bareilly		1	1			2	1	1	1	2	2	7	
Braenderup				1		1					1	1	
var. I 6,7:-:e,n,z15											1	1	
Gaminara	1	2		1	1	5							1
var. I 16:d:-		1				1							
Give var. 15+					1	1							
Inverness								1		2		3	
var. I 38:k:-	1	1				2	1	2	1	1	2	7	1
Meleagridis			1			1							
Muenchen	1	2	1		1	5		1	1	3	4	9	6
Newport									1			1	51
Rubislaw					1	1	1	3		1	6	11	1
Saintpaul					1	1	1	5	2	3	5	16	15
III 50:r:-					1	1							
var. III 50:-:-		1				1							
III 60:r:e,n,x,z15	1	2				3		2			4	6	
var. III 60:r:-							1					1	
# Positive/collected[1]	4/12	7/12	3/10	2/12	3/3	19/49	4/12	7/12	5/9	9/16	9/9	34/58	76/217[2]
Unique serotypes[1]	4	7	3	2	6	13	5	7	5	6	9	12	20+[2]

[1] Number of *Salmonella*-positive samples among the total collected. Individual samples often contained multiple serotypes.

[2] The remaining 141 cases were attributed to: Javiana (52 cases), Typhimurium (21), Enteritidis (16), Montevideo (7), Miami (6), I 13,23:b:- (6), Carrau (1), Heidelberg (1), Infantis (1), Kintambo (1), Mississippi (1), Sentftenberg (1), I 4,[5],12:i:- (1), and unidentified serotypes (26 cases).

Conclusions

Fruit and vegetable growers should be aware that *Salmonella* and *E. coli* levels in ponds are typically elevated after storms. Many serotypes of *Salmonella* found in fresh produce farm landscapes in south Georgia are similar to those found in human infections. Further study is needed assess the risk of illness posed by *Salmonella* in these environments, and to identify strategies to reduce risk.

Acknowledgements

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